Estimating Field Soil Loss by the Factor System[1]

The factor system for estimating soil loss combines in a rather simple equation the main elements that affect erosion. The approach is rational and not theoretical, as such an equation would be too complex for practical use even if it could be evaluated. The rational erosion equation is as follows:

$A = S\ L\ P\ C\ K$ in which

A is average annual soil loss in tons per acre,
S measures the effect of percent slope
L measures the effect of slope length,
P measures the effect of the supporting conservation practice,
C is the soil loss measured for different rotations on plots under uniform soil, slope, and rainfall conditions,
K is a soil factor enabling use of the data on soils other than that of the plot on which the values of C were secured.

The addition of a rainfall factor (R) to the equation would be required for application of the method over large areas. When the values of C are measured toward the center of a rainfall intensity area of limited variation, the inclusion of this factor is not required. This is the case for Missouri when data from the Missouri Soil Conservation Experiment Farm at McCredie are used.

SLOPE. The effect of percent slope on erosion with a loss of unity on the slope (3%) of the McCredie plots is shown in table 1.

Table 1.--Percent Slope Soil Loss Factors

% Slope	Factor	% Slope	Factor
1	.4	8	3.4
2	.7	9	3.9
3	1.0	10	4.5
4	1.4	11	5.1
5	1.8	12	5.7
6	2.3	15	7.7
7	2.8	20	11.5

1/ Cooperative Research Unit, Soil Conservation Service, - Missouri Agricultural Experiment Station, Agricultural Engineering Building, Columbia, Missouri.

The effect of slope length on erosion with a unity loss on the slope length (90 feet) of the McCredie plots is shown in table 2.

Table 2.--Slope Length Soil Loss Factors

Length-Ft.	Factor	Length	Factor
72.6	0.9	500	2.8
90	1.0	600	3.1
100	1.1	700	3.4
200	1.6	800	3.7
300	2.1	900	4.0
400	2.5	1000	4.2

Use of the slope length factors of table 2 will result in erroneous conclusions if the limits of application of the relationship are not considered in determining the slope length of a field. Soil loss increases with slope length only so long as the percent slope increases or remains constant. A decrease in percent slope generally results in deposition of soil a short distance beyond the point of decrease. The measured slope length for a field should be the shortest distance the runoff travels to reach this point.

CONTOURING. The relative reduction in soil loss by contouring varies with the steepness of slope. On the extremely flat slopes where the contour row grade approaches the land slope the reduction becomes small; also, as the land slope increases to the point that the capacity of the contour row to retain runoff disappears, the reduction in soil loss disappears. These factors are shown in table 3.

Table 3 --Practice Factors for Contouring

% Slope	P	% Slope	P
1	.74	8	.52
2	.60	9	.55
3	.54	10	.58
4	.52	11	.61
5	.50	12	.64
6	.50	15	.75
7	.51	20	.90

The problem of estimating soil loss with contouring may be simplified by combining the factors of table 1, 2 and 3 in a single table. This has been done in table 4.

Table 4.--Slope-Practice-Soil Loss Factors for Contouring

% Land Slope	Slope Length - Feet							
	90	200	300	400	500	600	800	1000
1	.3	.5	.6	.7	.8	.9	1.1	1.3
2	.4	.7	.9	1.1	1.2	1.3	1.6	1.8
3	.5	.9	1.1	1.3	1.5	1.7	2.0	
4	.7	1.2	1.5	1.8	2.0	2.3	2.7	
5	.9	1.4	1.9	2.3	2.5	2.8		
6	1.2	1.9	2.4	2.9	3.3	3.6		
7	1.4	2.3	3.0	3.6	4.0			
8	1.8	2.9	3.7	4.4	5.0			
9	2.2	3.5	4.5	5.4				
10	2.6	4.2	5.5	6.5				
11	3.1	5.0	6.5	7.7				
12	3.7	5.9	7.7					
15	5.8	9.3	12.1					
20	10.3	16.6	21.6					

Excess breaking over of contour rows occurs on the longer slopes. This is particularly serious with the more severe rain storms. Tentative slope length limitations for contouring are shown by the heavy line in table 4.

CROPPING. Soil losses under uniform slope, soil, and rainfall conditions vary over a wide range depending upon the cropping system. The crop sequence study at McCredie is one of the most intensive research projects on the subject in existence. The data from this project were used to prepare table 5. (following page)

Table 5.--Average annual soil loss in tons per acre for different rotations, from plots on Putnam silt loal soil of 3% slope, 90 feet long, and farmed up and down slope.

Rotation	Residue returned	Soil loss tons/acre
Corn-oats (no treatment)	Corn stalks	8.6
Corn-oats & sweet clover	Corn stalks & sw cl 1/	4.6
Corn-wheat & sweet clover	Sweet clover 1/	4.4
Corn-corn-oats-wheat & sw cl	1st corn stalks & sw cl	5.7
Corn-wheat-sw cl & timothy	Stubble only	2.9
Corn-wheat-grass & leg mead 1 yr	Stubble only	1.9
Corn-wheat-grass & leg mead 2 yrs	Stubble only	1.6
Corn-corn-oats-grass & legume meadow 1 yr	Corn stalks 1/	3.2
Corn-corn-oats-grass & legumes meadow 2 yrs	Corn stalks 1/	2.7
Corn-soybeans (drill)-wheat & sw cl	Stalks, straw & sw cl 1/	4.5
Corn-soybeans (row)-wheat & sw cl	Stalks, straw & sw cl 1/	5.3
Corn-soybeans (drill)-wheat-grass legume meadow	Corn stalks 1/	3.1
Corn-soybeans (row)-wheat-grass legume meadow	Corn stalks 1/	3.8
Corn-soybeans (drill)-wheat & lespedeza-lespedeza	Stubble only	5.3
Soybeans (drill) & w bar (grazed)	Stubble only	4.5
Soybeans (drill)-w bar-grass leg mead	Stubble only	1.2
Soybeans (row)-wheat-grass leg mead	Straw 1/	2.3
Oats (hay) & lesp (grazed)	Stubble only	3.0
Wheat & lesp (both grazed)	Stubble only	2.3
Oats & lesp (both for hay)	Stubble only	2.1
Wheat & lesp (grain & hay)	Stubble only	1.5
Wheat (grain)-grass leg mead 3 yrs (hay and pasture)	Stubble only 1/	0.9
Timothy lesp (continuous) (grazed)	Stubble only	0.5

1/ Losses computed from crop sequence data.

AN EROSION ESTIMATE FOR THE CLAYPAN SOIL. Solution of the erosion equation by use of factors from tables 1, 2 and 5, with P and K both equal to 1, will give the expected loss for up-and-down-hill farming on claypan soils. With contour farming the expected loss would be the product of a slope-practice-soil loss factor from table 4 and the rotation loss from table 5.

LIMITING SOIL LOSSES. Perhaps no single question in the field of soil conservation is more difficult to answer than, "What is the allowable soil loss for a given soil?" Involved in the answer are the rate of weathering, size of particles and mineral content of the underlying material, climate, and a host of other variables. No single yardstick can be used in answering the question. But because organic matter reflects better than any other quality subject to measurement the effects of climate, mineral nutrient availability, and loss of the soil body from the surface, it has been used to throw some light on the problem.

There are some who think that erosion should be permitted to such an extent that mineral nutrients available in the subsoil would be incorporated in the plow layer at a rate commensurate with needs. In most, if not all, our soils in Missouri the underlying material simply is not that high in mineral nutrients. Even if it were, it is doubtful if the organic fraction could be maintained in face of such high losses at a level high enough to contribute its beneficial effects to structure and plant nutrition.

As a first approximation of allowable soil losses, subject to revision as more data become available, annual changes (%) in organic matter content have been plotted against soil loss (tons/acre). Data from the control plots at Bethany and Clarinda were used for Shelby and Marshall, respectively, and from the crop sequence plots at McCredie for Putnam. In each instance the change in organic matter content from the previous sampling was plotted against the soil loss during the same period on an annual basis. The line fitted to the points crosses the "no change" line between 3 and 4 tons per acre per annum for Marshall, 4 and 5 tons for Shelby, and 2 and 3 tons for Putnam. In other words, annual losses in excess of these amounts were accompanied by a decrease in fertility (organic matter) level. Fertility level was maintained or increased on plots having losses less than these amounts. As a basis for planning, it is suggested that a loss of 4 tons per acre per year be used for Marshall and Shelby and 3 tons for Putnam.

Data are not available for other soils of the state, but considering the soil characteristics, it seems safe to suggest the 4 ton figure for all except the claypan, Osark, and border Ozark soils. For these latter areas, the value of 3 tons would be preferred.

THE SOIL FACTOR IN THE EROSION EQUATION. Physical limitations prohibit comprehensive investigations on all soils of the state. Yet it is well known that under comparable conditions of slope, cropping, etc., all Missouri soils would not erode at the same rate. Some efforts have been made to place a value on the effect of soil characteristics, but up to the present, these are only estimates serving until more exact information is available.

Using the slope relationships already discussed and keeping the cropping system comparable, values relative to Putnam have been computed for Shelby, Marshall, and Fayette. These data were collected at Bethany, Clarinda, Iowa, and LaCrosse, Wisconsin. In the case of Fayette, an adjustment was made to correct for a rainfall difference. The results of these computations were:

Soil	Relative Soil Loss
Shelby	1.3
Marshall	1.2
Fayette	1.2
Putnam	1.0

From a theoretical point of view these values seem logical if one considers the structure and permeability together. Putnam has the poorest structure of any. It is easily dispersed, and particles on the surface arrange themselves in a shingle effect. Such an arrangement on the surface sheds water without the movement of excessive soil. Shelby, Marshall, and Fayette, on the other hand, with more stable aggregates that remain independent, are more easily transported once the rate of rainfall exceeds permeability. Shelby, with its tighter subsoil, should logically be more erosive than Marshall on this basis under conditions of equal rainfall intensity.

Observations in the field, principally by Krusekopf, would indicate the Ozark soils are less erosive than the Putnam. Here again poor structure permits a sealing on the surface. Streams in the Ozark region always react more quickly to rain than those in North Missouri despite the high percentage of trees, adding credence to this reasoning. Krusekopf would place the Western Ozark Border soils in the same category as the Ozark proper, but would class the Eastern Ozark Border with the Marshall and River Hills region.

Sufficient data are not available to place a value on each soil of the state, but there is some basis for suggesting the values listed in Table 6 by soil areas. (See Mo. Agr. Exp. Sta. Cir. 304, August 1945).

Table 6.--Soil Factors in Missouri

Soil Area	Factor
Shelby and associated glacial soils	1.3
River Hills, Marshall and associated loess soils, and Eastern Ozark Border	1.2
Claypans (NE and SW level prairies)	1.0
Ozarks and western Ozark border	.8

TERRACING. Estimating soil loss with terracing follows a somewhat different pattern than with contouring as the length of slope is limited by the spacing recommendations. Slope factors for terracing are shown in Table 7.

Table 7.. -- (P) Slope-Soil Loss Factors for Terracing

% Slope	Factor	% Slope	Factor
1	.4	8	2.4
2	.6	9	2.8
3	.8	10	3.3
4	1.0	11	3.8
5	1.3	12	4.5
6	1.6	15	6.6
7	2.0	20	10.0

The soil movement to the terrace channel is the product of a factor from table 7 and the rotation loss from table 5. Experiments have shown that the loss from the terrace channel in runoff will be about 10% of this product. On the flatter slopes the actual deposition in the channel is generally of little consequence, even though it is 90% of the total soil movement. The channel deposition will reach a significant amount on the steeper slopes unless low soil loss rotations are used. The use of the more intensive rotations can be extended to steeper slopes by periodic moving of the deposition soil back up the slope. This can be readily accomplished by turning all furrow slices up slope whenever the cropping plan calls for plowing. A two-way or hillside plow will be required in place of the conventional plow.

Selection of a rotation to limit channel deposition to a practical amount can be easily done by use of table 8. If the plot soil loss for a selected rotation from table 5 does not exceed the tabulated value for the land slope of the field and the method of plowing shown in table 8, the channel deposition will not be excessive. For other soils than the Putnam, the plot rotation soil loss of table 5 must be multiplied by the appropriate soil factor from table 6 before checking with the tabulated values in table 8.

Table 8.--Allowable Plot Soil Losses for Different Methods of Plowing Terraced Land

Land Slope	Allowable plot rotation soil loss				
	Conventional contour plowing or discing	Up-hill plowing once in indicated number of years			
		1	2	3	4
1	14.0	39.6	26.8	22.6	20.5
2	9.2	30.6	20.0	16.3	14.6
3	6.8	25.1	16.0	13.0	11.4
4	5.3	21.2	13.3	10.6	9.4
5	4.2	17.4	10.8	8.6	7.5
6	3.3	14.6	9.0	7.1	6.1
7	2.8	12.8	7.8	6.1	5.3
8	2.3	10.9	6.6	5.1	4.4
9	1.9	9.5	5.8	4.5	3.9
10	1.7	8.4	5.1	3.9	3.3
11	1.4	7.5	4.5	3.4	2.9
12	1.2	6.5	3.9	3.0	2.5
15	.8	4.5	2.7	2.1	1.8
20	.5	3.0	1.8	1.4	1.2